(NASA-CR-164349) RADAR INVESTIGATION OF ASTEROIDS Semiannual Status Report, 1 Nov. 1980 - 30 Apr. 1981 (Cornell Univ., Ithaca, N. Y.) 14 p HC A02/MF A01 CSCL 03B

N81-25018

Unclas
G3/91 42424

CORNELL UNIVERSITY

Center for Radiophysics and Space Research

ITHACA, N. Y.

SEMI-ANNUAL STATUS REPORT

to the

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

under

NASA Grant NAGW-116

RADAR INVESTIGATION OF ASTEROIDS

November 1, 1980--April 30, 1981

Principal Investigator: Professor Steven J. Ostro

CENTER FOR RADIOPHYSICS AND SPACE RESEARCH
CORNELL UNIVERSITY
ITHACA, NEW YORK 14853

SEMI-ANNUAL STATUS REPORT

NASA Grant NAGW-116

November 1, 1980--April 30, 1981

RADAR INVESTIGATION OF ASTEROIDS

Prepared May 1981

Steven J. Ostro
Principal Investigator

TABLE OF CONTENTS

		page
I.	SUMMARY OF PROGRESS	1
II.	FUNDING STATUS AND PERSONNEL ON GRANT	2
III.	STATUS OF DATA ANALYSIS	2
	Psyche	4
	Vesta	4
	Apollo	7
	Quetzalcoatl	7

I. SUMMARY OF PROGRESS

The research supported under NAGW-116 has been proceeding as planned. Each of the five minor planets (4 Vesta, 7 Iris, 16 Psyche, 1862 Apollo, and 1915 Quetzalcoatl) proposed as targets of radar observation has been detected at significant levels of echo power. Except for Vesta, none of these asteroids had been detected previously.

By transmitting circularly polarized waves and dividing the data acquisition period equally between reception in the <u>same</u> rotational sense of <u>circular</u> polarization as transmitted (i.e., the SC sense) and reception in the <u>opposite circular</u> sense (i.e., the OC sense), the radar polarization properties of the five asteroids have been assessed. Prior to 1980, the $\lambda 12.6$ polarization ratio, μ_C, of SC echo power to OC echo power, had not been accurately estimated for any minor planet.

For both Apollo and Iris, echo strength was sufficient to permit time-delay resolution of the radar echoes using a binary phase-coded CW waveform well matched to the radar signatures of the targets. The Iris ranging results mark the first radar measurement of the distance to a main-belt asteroid.

Research efforts during the past six months have concentrated on (i) acquisition of radar data at Arecibo; (ii) examination of the raw data; (iii) reduction of the unmodulated (CW) data to background-free, calibrated

spectra; (iv) integration and coherent analyses of the phase-coded data; and (v) calculation of Doppler shifts and preliminary values for echo limb-to-limb bandwidths, radar cross sections, and circular polarization ratios. The next six months will focus on (i) refinement of all these parameters; (ii) physical interpretation of the results, and (iii) publication of the results. Already, it is apparent that each target has its own, unique set of radar properties, and that the asteroids observed to date have radar properties distinct from those of the rocky terrestrial planets and those of the icy Galilean satellites.

II. FUNDING STATUS AND PERSONNEL ON GRANT

The period of this report has seen spending at the anticipated rate.

Two persons have been hired for a two-month period this summer to assist the principal investigator with computer modelling and analysis of the data: Karl Vogel, a graduating senior in the Department of Mechanical and Aerospace Engineering; and Brenda McFarlane, a junior in the Department of Computer Science.

III. STATUS OF DATA ANALYSIS

A computer program has been written to remove the background noise baseline from raw CW spectra, and to normalize the resulting signal to standard deviations of

the noise fluctuations. Efforts by the principal investigator to calibrate the sensitivity of the Arecibo telescope's 2380 MHz (λ12.6 cm) feed suggests that the antenna gain is an erratic function of zenith angle and azimuth. For this reason, systematic uncertainties in estimates of radar cross section probably cannot be reduced below the $\sim$ 25% level. Within this uncertainty, the radar spectra can be normalized to the radar cross section equivalent, in units of km^2, of received echo power. All CW data covered under this grant have been so reduced.

Iris: OC echoes were easily detected, but an SC echo could not be detected at all, even after summing the three nights' data. It is possible to assign an upper limit on the circular polarization ratio: $\mu_c \lesssim 0.1$. This result requires that the Iris echoes are due to single reflections from surfaces that are large and smooth at the scale of the observing wavelength, 12.6 cm. It rules out substantial subsurface multiple scattering and surface roughness at decimeter scales. The weighted-mean OC spectrum of Iris (Fig. 1a) is very broad and hence is not caused by the "quasispecular" scattering seen in radar echoes from the terrestrial planets. The spectral edges correspond to echoes from the planetary limbs, and are consistent with the limb positions (arrows) expected from a priori estimates of Iris' spin vector and mean radius ($\sim$ 105 km). Since strong echoes are received from limb regions, i.e., at

oblique angles of incidence, the topography at scales at least as large as one meter must be extremely rough.

Figure 2 shows 70 μs and 40 μs delay-resolved echoes from Iris. The apparent confinement of echo to $\lesssim$ 200 μs in delay (corresponding to 30 km in radial extent) is peculiar, given the confirmation by the CW radar data of a mean radius equal to ∼ 105 km (corresponding to 700 μs in delay). It seems that Iris must be very elongated and/or flattened.

Psyche (Fig. 1b) is the first M-type asteroid detected by radar. Its λ12.6-cm, OC radar reflectivity is about 2.5 times as large as that observed for any other rocky body. An effort is underway to model Psyche's reflectivity in terms of the metal-to-silicate ratio, particle size distribution, and density of the surface material.

Vesta (Fig. 1c) was detected at a signal-to-noise ratio of about 8 standard deviations, vs. about 4 std. devs. for the previous detection in 1979. The bandwidth of the recently acquired spectrum suggests that Vesta's rotation period is 5.34 hours, not 10.68 hours (claimed by some optical observers on the basis of lightcurve data). However, Vesta's radar reflectivity is apparently lower than that estimated from the earlier, weaker data, possibly due in part to a difference of ∼ 30° in subradar latitude between the 1979 and 1981 apparitions. As with Iris, SC echoes could not be detected

Fig. 1:
CW SPECTRA

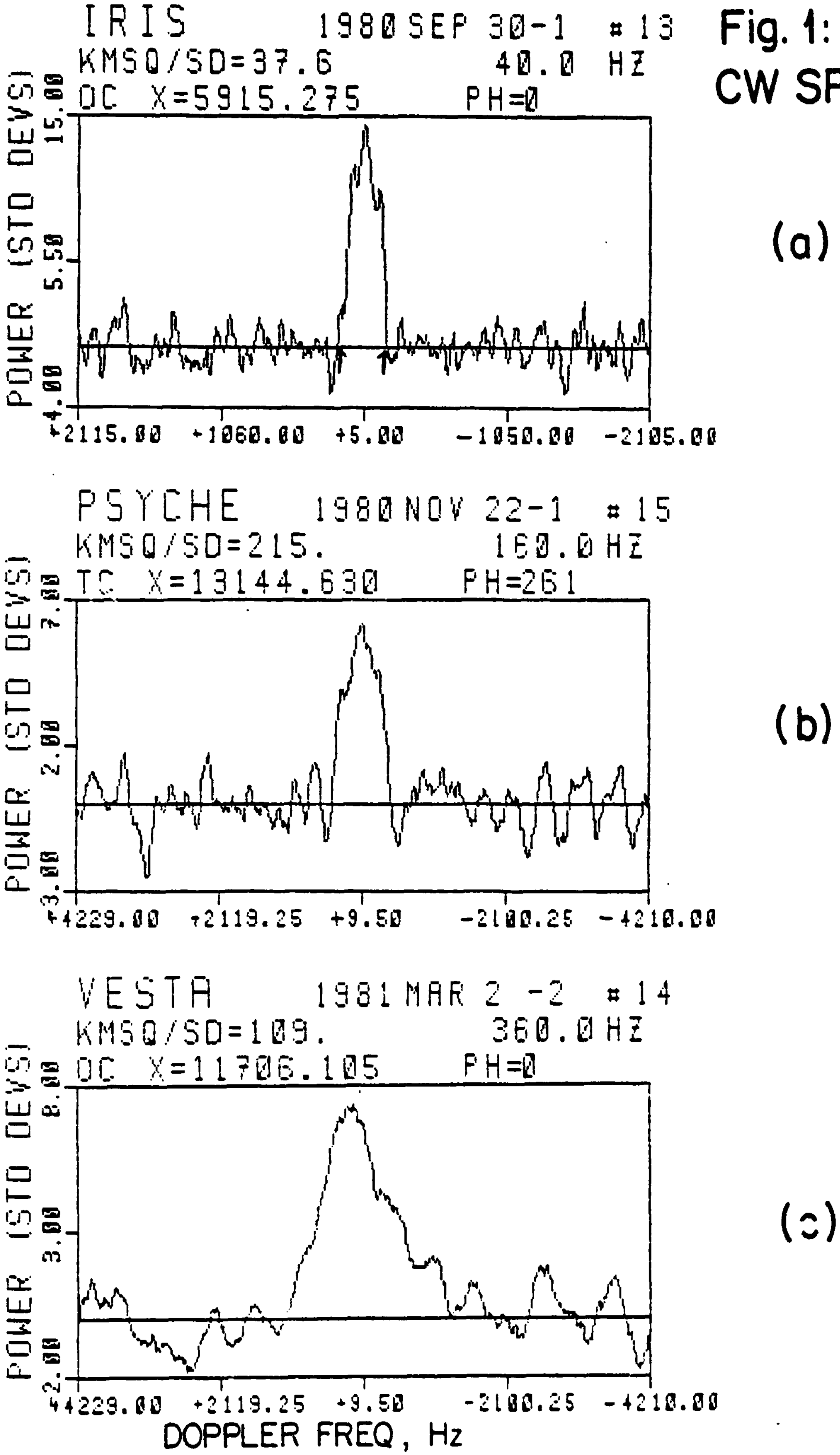
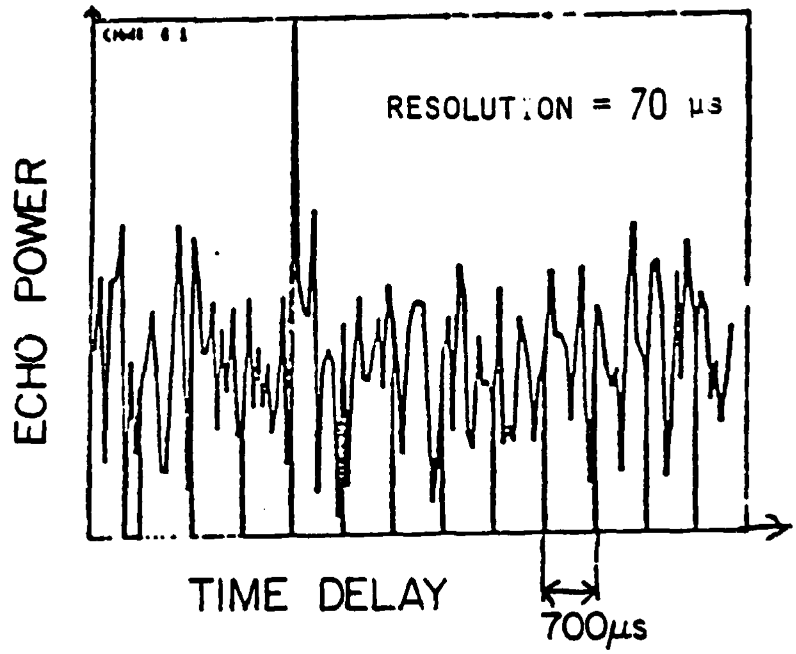
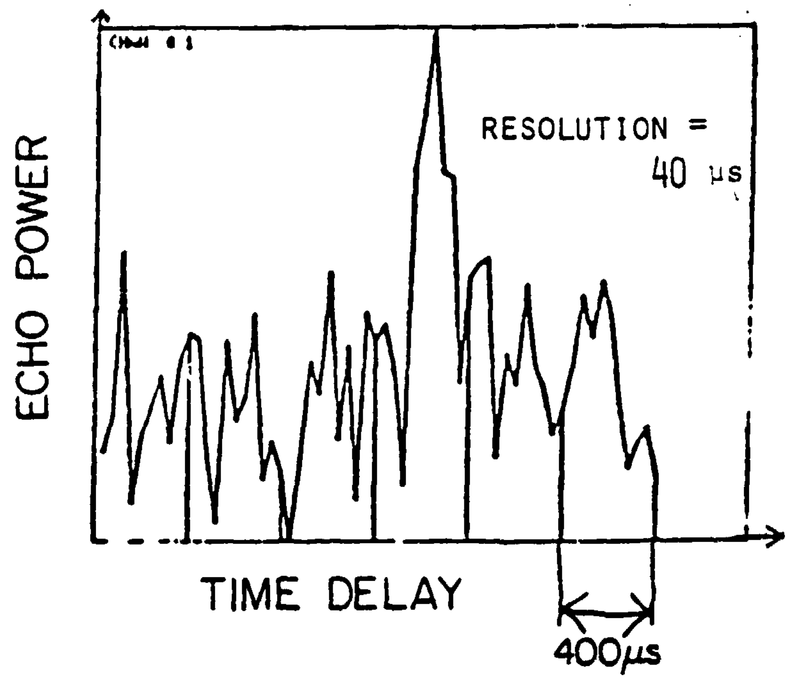


Fig. 2:

IRIS RANGING RUNS





for either Psyche or Vesta. An upper limit: $\mu_C \lesssim 0.3$ applies to each of the latter two bodies.

Apollo was detected on each of the eight nights: November 13-20. On several nights the roundtrip delay was determined to within about 5 μs, corresponding to 750 m in distance and a fractional precision of one part in 10^7. Doppler shifts, accurate to 1 Hz, or one part in 10^9, were determined on each night. These results will permit substantial improvement in our knowledge of Apollo's orbital elements.

Figures 3a and 3b show single-night weighted mean spectra received in the OC and SC senses, respectively. The circular polarization ratio varies irregularly as the asteroid rotates, averaging about 0.35. Substantial variation in spectral shape as a function of rotational phase is prominent in the spectra. For example, Fig. 4 shows total-power spectra (OC + SC) separated by $\sim 35°$ of rotational phase.

Quetzalcoatl (Fig. 5) was detected in both the OC and SC polarizations. Its polarization ratio is similar to Apollo's. These Earth-crossing asteroids are apparently rougher at decimeter scales than their main belt cousins. Preliminary estimates of Quetzalcoatl's limb-to-limb bandwidth and reflected echo power indicate a radius no larger than $\sim$ 400 m, establishing this asteroid as the smallest extraterrestrial object detected so far with Earth-based radar.

Fig. 3a:

APOLLO OC SPECTRA

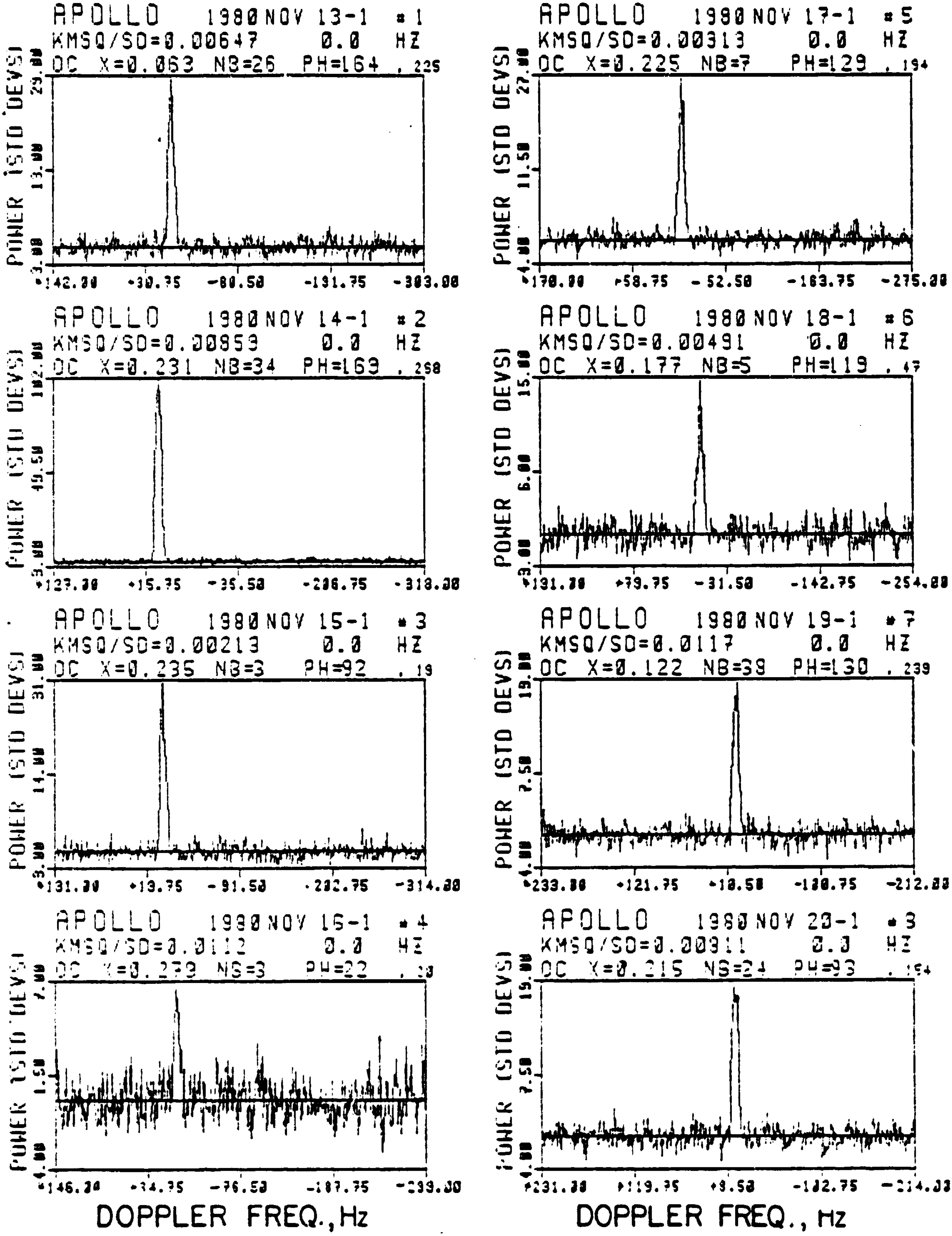


Fig. 3b.

APOLLO SC SPECTRA

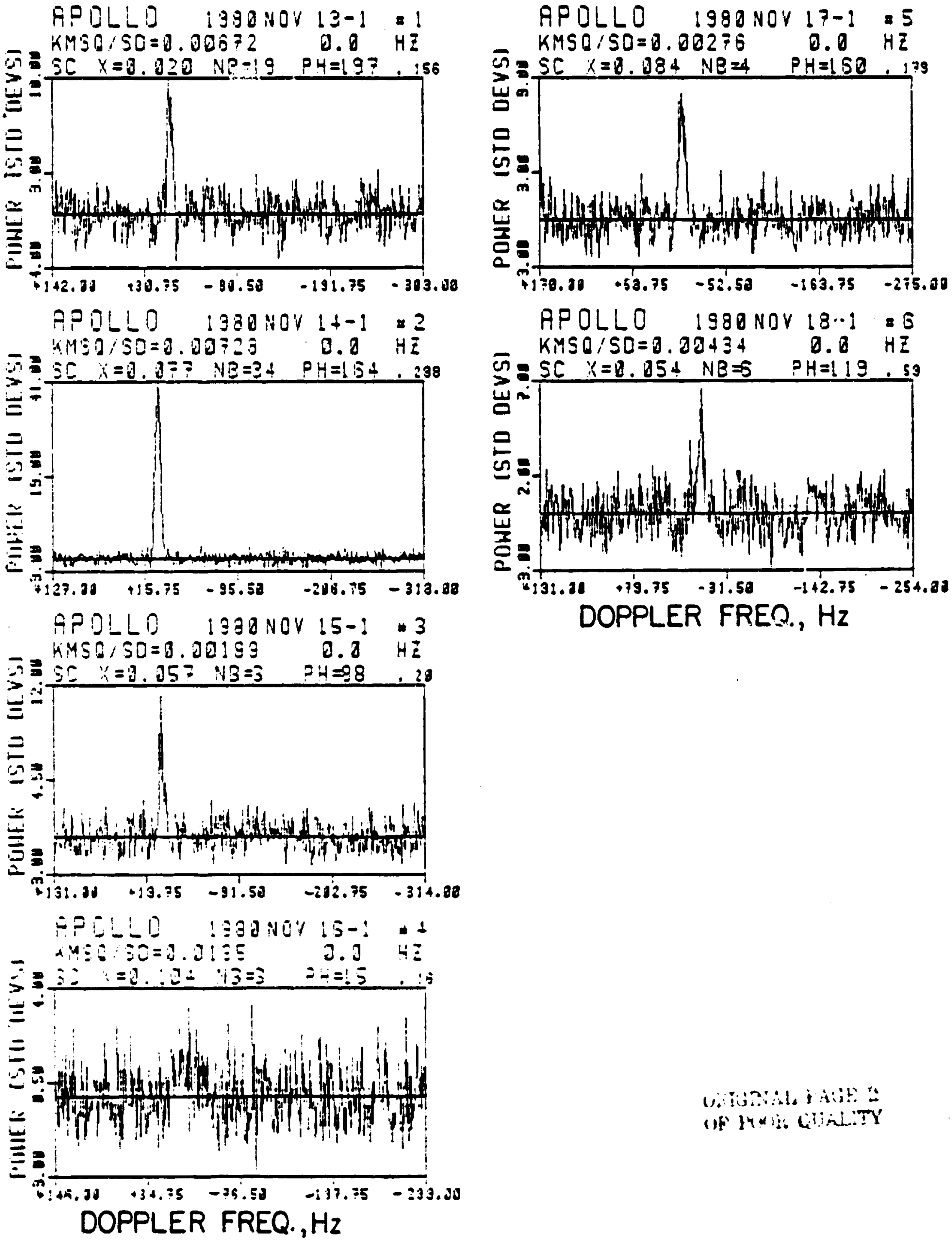


Fig. 4:

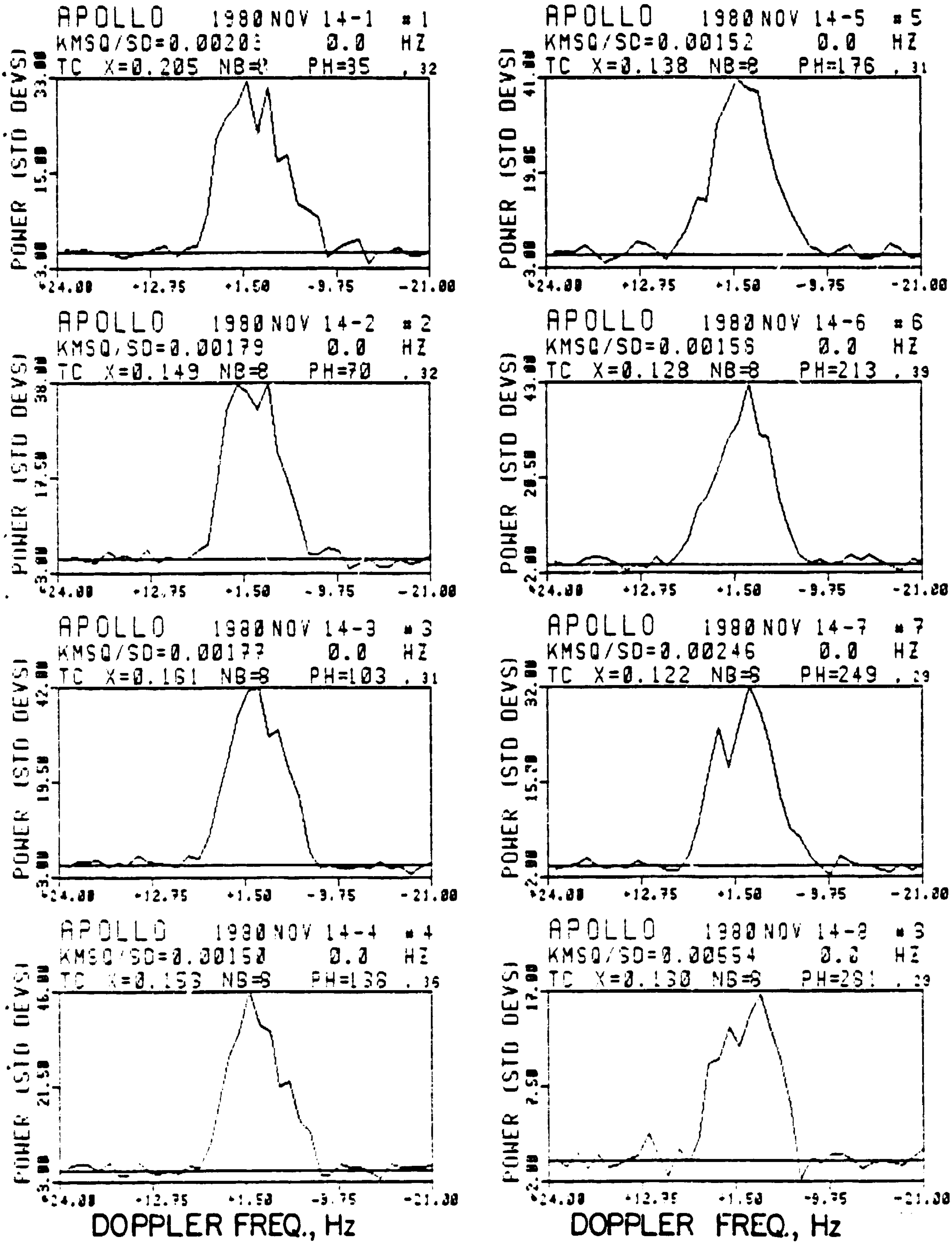
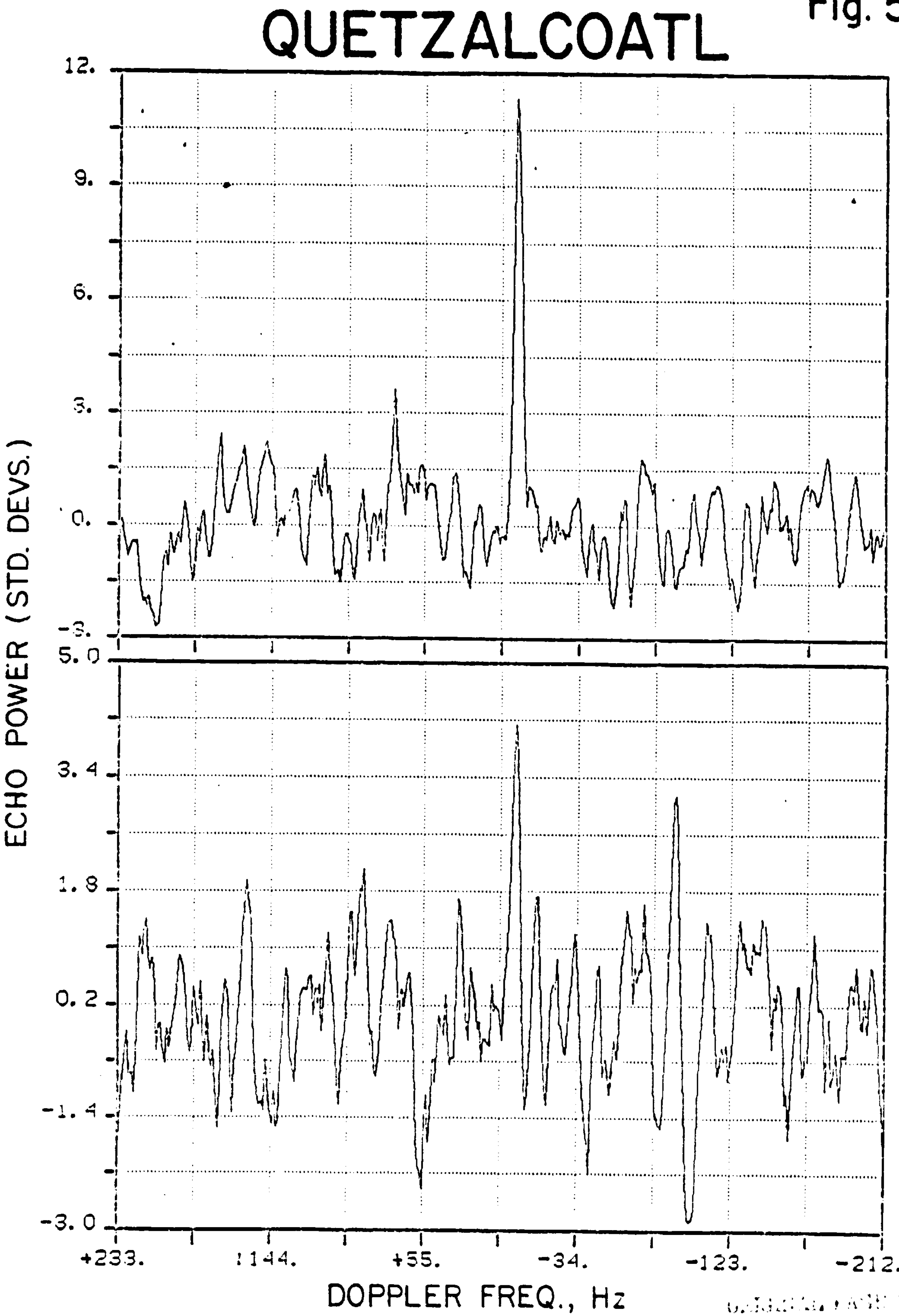

APOLLO 1980 NOV 14-1 # 1
KMSQ/SD=0.00203 0.0 HZ
TC X=0.205 NB=8 PH=35 , 32
APOLLO 1980 NOV 14-5 # 5
KMSQ/SD=0.00152 0.0 HZ
TC X=0.138 NB=8 PH=176 , 31
APOLLO 1980 NOV 14-2 # 2
KMSQ/SD=0.00179 0.0 HZ
TC X=0.149 NB=8 PH=70 , 32
APOLLO 1980 NOV 14-6 # 6
KMSQ/SD=0.00155 0.0 HZ
TC X=0.128 NB=8 PH=213 , 39
APOLLO 1980 NOV 14-3 # 3
KMSQ/SD=0.00177 0.0 HZ
TC X=0.161 NB=8 PH=103 , 31
APOLLO 1980 NOV 14-7 # 7
KMSQ/SD=0.00246 0.0 HZ
TC X=0.122 NB=8 PH=249 , 29
APOLLO 1980 NOV 14-4 # 4
KMSQ/SD=0.00150 0.0 HZ
TC X=0.153 NB=8 PH=136 , 35
APOLLO 1980 NOV 14-8 # 8
KMSQ/SD=0.00554 0.0 HZ
TC X=0.130 NB=8 PH=281 , 29
POWER (STD DEVS)
+24.00 +12.75 +1.50 -9.75 -21.00
DOPPLER FREQ., Hz

Fig. 5:


QUETZALCOATL
ECHO POWER (STD. DEVS.)
12.
9.
6.
3.
0.
-3.
5.0
3.4
1.8
0.2
-1.4
-3.0
+233.
+144.
+55.
-34.
-123.
-212.
DOPPLER FREQ., Hz